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# RESEARCH MEMORANDUM

EFFECT OF AN END PLATE ON THE AERODYNAMIC CHARACTERISTICS  
OF A 20.55° SWEPTBACK WING WITH AN ASPECT RATIO OF 2.67  
AND A TAPER RATIO OF 0.5

TRANSONIC - BUMP METHOD

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RESEARCH MEMORANDUM

EFFECT OF AN END PLATE ON THE AERODYNAMIC CHARACTERISTICS  
OF A  $20.55^\circ$  SWEPTBACK WING WITH AN ASPECT RATIO OF 2.67  
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TRANSONIC-BUMP METHOD

By James M. Watson

SUMMARY

An investigation by the transonic-bump method conducted in the Langley high-speed 7- by 10-foot tunnel to determine the effect of an end plate on the aerodynamic characteristics of a  $20.55^\circ$  sweptback wing with an aspect ratio of 2.67 and a taper ratio of 0.5 indicated that the end plate affected the aerodynamic characteristics of the wing at transonic Mach numbers in the same manner as has been observed for swept and unswept wings at low speeds.

INTRODUCTION

The feasibility of using end plates on wings is being investigated as part of the National Advisory Committee for Aeronautics program to improve the aerodynamic characteristics of wings at transonic speeds. Previous investigations at low subsonic speeds (references 1 and 2) have generally shown that the addition of end plates to wings resulted in increased lift-curve slopes with only small decreases in maximum lift-drag ratios. In addition, improvements in the lateral stability characteristics and increased control effectiveness have resulted from the addition of end plates to swept wings (reference 1).

The present investigation was made by the transonic-bump method (reference 3) in the Langley high-speed 7- by 10-foot tunnel to determine the aerodynamic characteristics in pitch at transonic speeds of two semi-span wings having an aspect ratio of 2.67, a taper ratio of 0.5, and sweepback of  $20.55^\circ$ , one wing with and one wing without an end plate. The data were obtained through an angle-of-attack range of  $-4^\circ$  to  $12^\circ$  and a Mach number range of 0.6 to 1.18.

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## SYMBOLS

$C_L$  lift coefficient  $\left( \frac{\text{Twice panel lift}}{qS} \right)$

$C_D$  drag coefficient  $\left( \frac{\text{Twice panel drag}}{qS} \right)$

$C_m$  pitching-moment coefficient referred to 0.25 $\bar{c}$   
 $\left( \frac{\text{Twice panel pitching moment}}{qS\bar{c}} \right)$

$C_B$  bending-moment coefficient about root chord line (at plane of symmetry)  $\left( \frac{\text{Root bending moment}}{q \frac{S}{2} \frac{b}{2}} \right)$

$q$  effective dynamic pressure over span of model, pounds per square foot ( $\rho V^2/2$ )

$S$  twice wing area of semispan model, 0.167 square foot

$(L/D)_{\max}$  maximum lift-drag ratio

$C_{L\alpha}$   $\partial C_L / \partial \alpha$ , per degree of angle of attack

$\bar{c}$  mean aerodynamic chord of wing, 0.25 foot  $\left( \frac{2}{S} \int_0^{b/2} c^2 dy \right)$

$c$  local wing chord, feet

$b$  twice span of semispan model, 0.67 foot

$y$  spanwise distance from wing root, feet

$\rho$  air density, slugs per cubic foot

$V$  free-stream velocity, feet per second

$M$  effective Mach number over span of model

$M_l$  local Mach number

$M_a$  average chordwise local Mach number

$R$  Reynolds number of wing based on  $\bar{c}$

$\alpha$  angle of attack, degrees

Subscripts:

$M$  at constant Mach number

$C_{L=0}$  at zero lift

### MODEL AND APPARATUS

The two semispan wings used in the investigation had  $20.55^\circ$  of sweepback referred to the quarter-chord line, an aspect ratio 2.67, and a taper ratio 0.5. These wings were constructed of  $\frac{1}{8}$ -inch sheet steel with the leading and trailing edges beveled (fig. 1). A  $\frac{1}{8}$ -inch sheet-steel end plate with beveled leading and trailing edges was brazed to the tip of one of the wings. The wings were mounted on an electrical strain-gage balance enclosed within the bump. The pitching moments were measured about the quarter chord of the mean aerodynamic chord and the bending moments were measured about the root chord. The air flow into and out of the balance chamber around the root of the wing was kept at a minimum by using a very finely knit, sponge-like material glued beneath the bump surface and free to slide on the surface of the models as a seal. (See fig. 2.)

### TESTS

The tests were conducted in the Langley high-speed 7- by 10-foot tunnel and used the transonic-bump method. This method is an adaptation of the NACA wing-flow technique for obtaining transonic speeds and consists in the mounting of a model in the high-velocity flow field generated over the curved surface of a bump located on the tunnel floor. (See reference 3.)

Typical contours of local Mach numbers in the region of the model location on the bump, obtained from surveys with the clear bump, are shown in figure 3. A Mach number gradient exists over the span of the model; this gradient results in a difference of about 0.05 at the lowest Mach number, 0.06 at the highest Mach number, and a maximum difference of about 0.08 at a Mach number of about 1.0. The chordwise Mach number

variation is generally less than 0.01 except at the higher Mach numbers where the variation becomes as great as 0.03. No attempt has been made to determine the effects of these spanwise and chordwise variations in Mach number. The long-dashed lines shown near the wing root indicate the extent of the bump boundary layer and represent a local Mach number 5 percent below the maximum value at each chordwise station. The effective test Mach number was obtained from contour charts similar to those of figure 3 and from the relationship

$$M = \frac{2}{S} \int_0^{b/2} cM_a dy$$

The variation of average test Reynolds number with Mach number is presented in figure 4.

Force and moment data were obtained for the wings through a Mach number range of 0.60 to 1.18 and an angle-of-attack range of  $-4^\circ$  to  $12^\circ$ .

Jet-boundary corrections have not been applied inasmuch as the boundary conditions to be satisfied have not been accurately defined. These corrections are believed to be small, however, inasmuch as the effective flow field is large compared to the small size of the wings.

#### RESULTS AND DISCUSSION

The aerodynamic characteristics in pitch of the wings, one wing with and one wing without an end plate, are presented in figure 5. A comparison of the various parameters for the two configurations is given in figure 6. The slopes summarized in figure 6 were taken over a lift-coefficient range of about  $\pm 0.1$ .

#### Lift and Drag Characteristics

The lift-curve slopes  $(C_{L_a})_M$  (fig. 6) of the wing without an end plate increased from a value of about 0.056 at a Mach number of 0.6 to 0.076 at a Mach number of 0.94. Mach number increases above 0.94 decreased the value of  $(C_{L_a})_M$  to about 0.062 at  $M = 1.18$ . The addition of the end plate caused an increase in  $(C_{L_a})_M$  (at the low lift coefficients) of 0.015 at  $M = 0.6$ , 0.024 at  $M = 0.94$ , and 0.015 at  $M = 1.18$ . The higher lift-curve slope caused by the wing with the end plate indicates

an increase in the effective aspect ratio. A calculated effective aspect ratio of 3.94 was obtained from reference 4 for the wing with end plate.

The estimated lift-curve slopes shown in figure 6 were obtained from references 4 and 5 (by the use of the Mach number expansion presented therein) and indicate excellent agreement at the lower test Mach numbers.

The drag coefficient (fig. 6) of the wing with an end plate, at a lift coefficient of zero, was slightly higher than that of the wing without an end plate. The drag rise occurred at a slightly lower Mach number for the wing with an end plate. At higher lift coefficients (approx. 0.5) the drag of the wing with an end plate was approximately the same as that of the wing without an end plate (fig. 5); this fact indicated that the reduction in induced drag of the wing with an end plate, due to the higher effective aspect ratio, approximately counterbalanced the drag of the end plate. The value of  $(L/D)_{max}$  of the wing with an end plate was about the same as the value for the wing without an end plate (fig. 6) throughout the Mach number range investigated.

#### Root-Bending-Moment Characteristics

The variation of root-bending-moment coefficient with lift coefficient (fig. 5 or 6) of the wing with an end plate was about 10 percent larger over most of the Mach number range than that of the wing without an end plate and indicated that the end plate caused an outward movement of the lateral center of pressure (fig. 6).

#### Pitching-Moment Characteristics

The wing with an end plate (fig. 5) exhibited an increase in longitudinal stability at the low lift coefficients over that of the wing without an end plate. The aerodynamic center, near zero lift coefficient, of the wing without an end plate was located at about  $0.14\bar{c}$  at  $M = 0.6$  and moved rearward to about  $0.43\bar{c}$  at  $M = 1.18$ . The aerodynamic center of the wing with an end plate showed the same general trends with Mach number but was from 4 to 6 percent of the chord behind that of the wing without an end plate (see fig. 6).

#### CONCLUSIONS

An investigation by the transonic-bump method was conducted in the Langley high-speed 7- by 10-foot tunnel to determine the effect of an end plate on the aerodynamic characteristics of a  $20.55^\circ$  sweptback wing with an aspect ratio of 2.67 and a taper ratio of 0.5. The addition of

the end plate increased the lift-curve slope, had a negligible effect on the maximum lift-drag ratio, and increased the longitudinal stability at all Mach numbers investigated. Similar results have been previously observed from the addition of end plates to swept and unswept wings at low speeds.

Langley Aeronautical Laboratory  
National Advisory Committee for Aeronautics  
Langley Air Force Base, Va.

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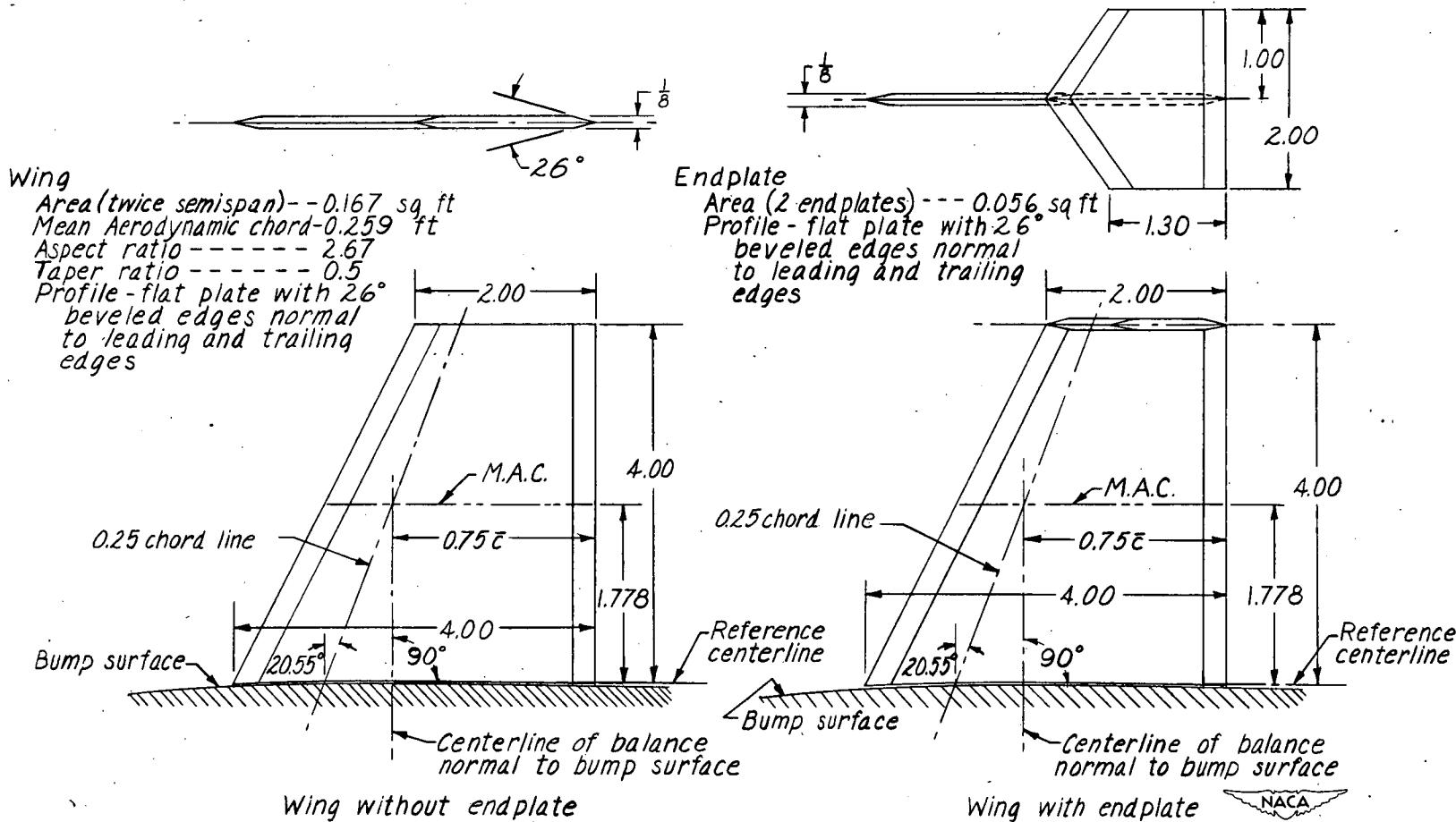


Figure 1.- General arrangement of the two wings swept back  $20.55^\circ$ , one wing with and one wing without an end plate. (All dimensions are in inches unless otherwise noted.)

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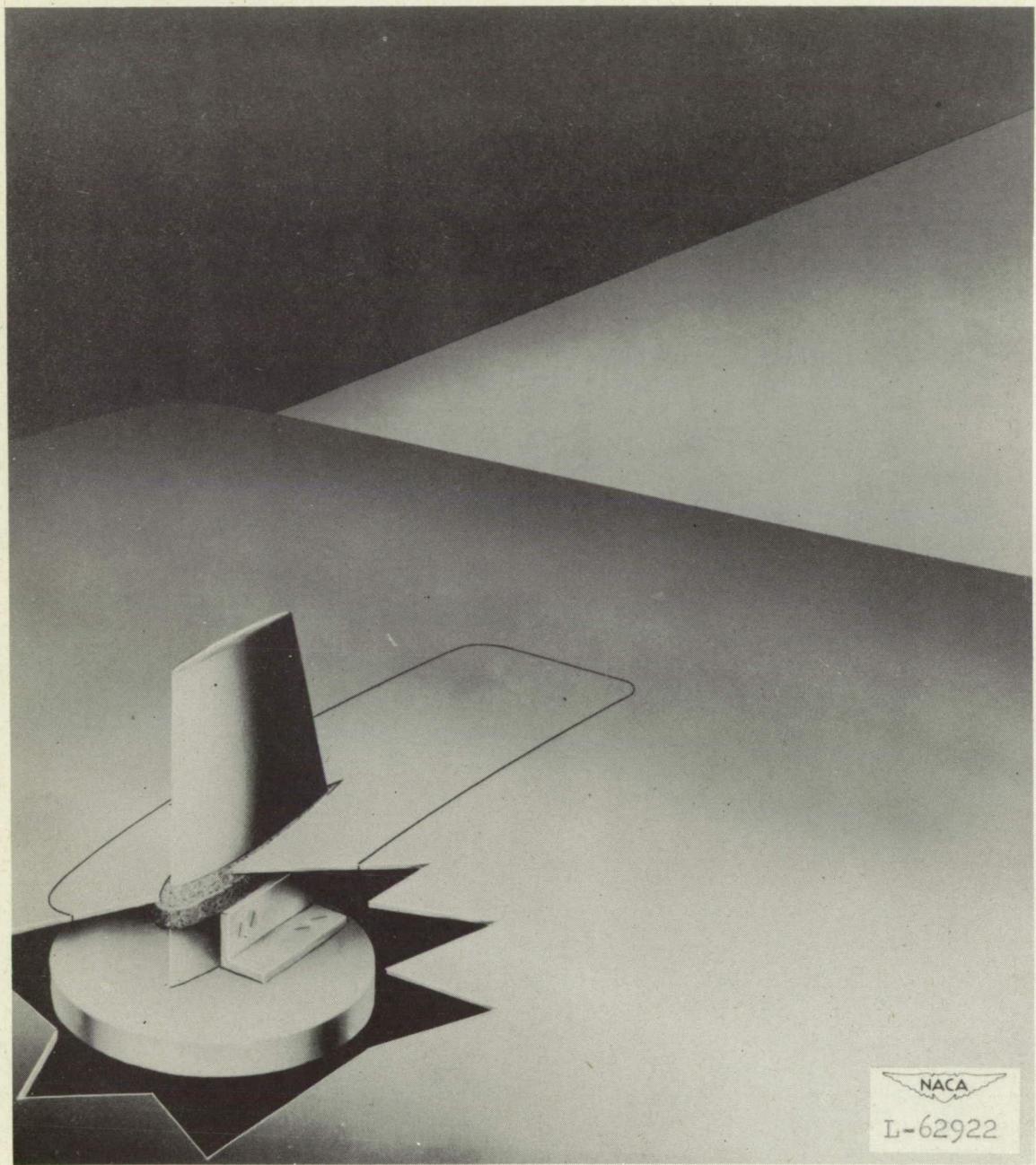


Figure 2.- Typical model installation with sponge seal on the transonic bump in the Langley high-speed 7- by 10-foot tunnel.

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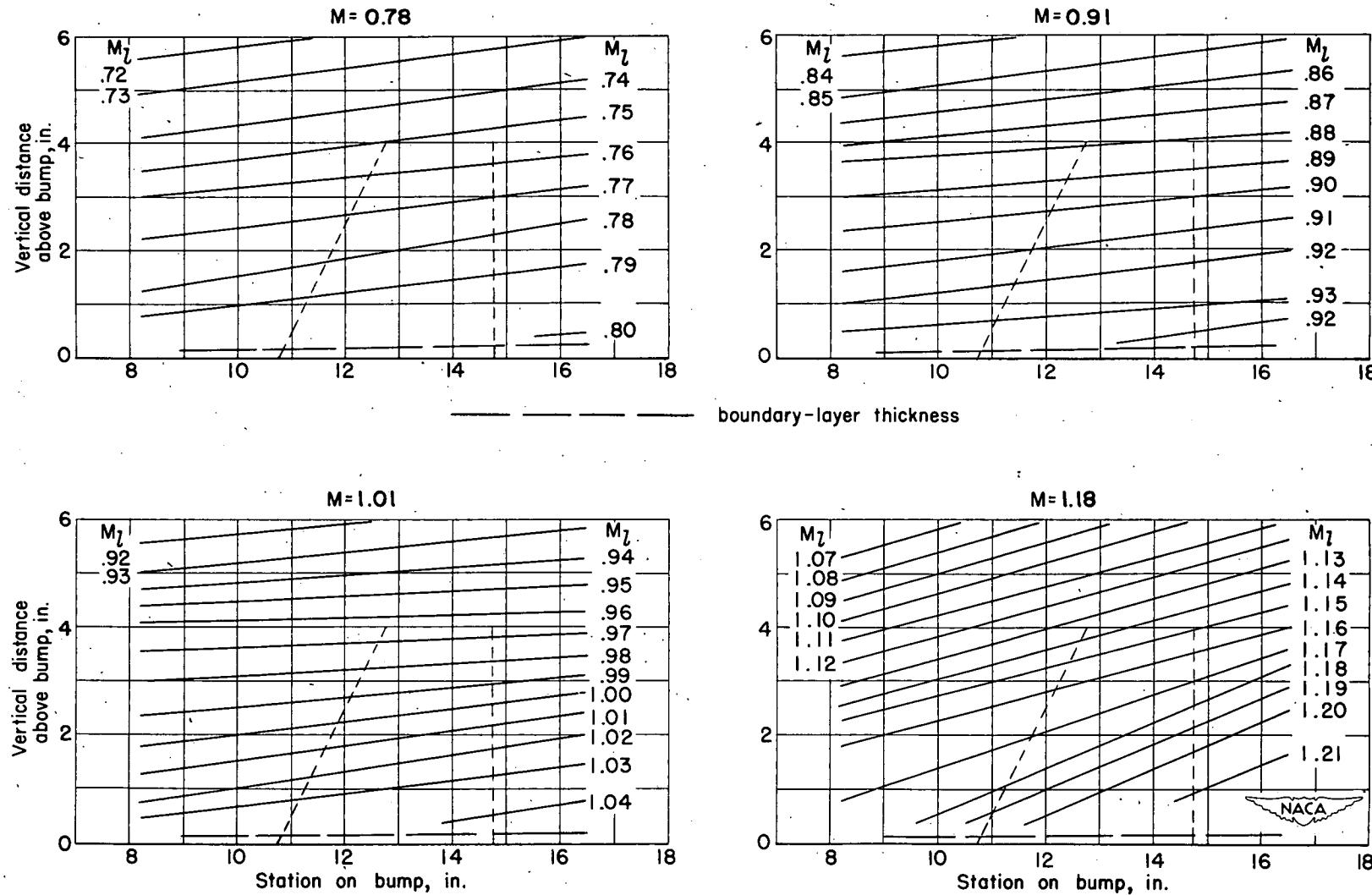


Figure 3.- Typical Mach number contours over transonic bump in region of model location.

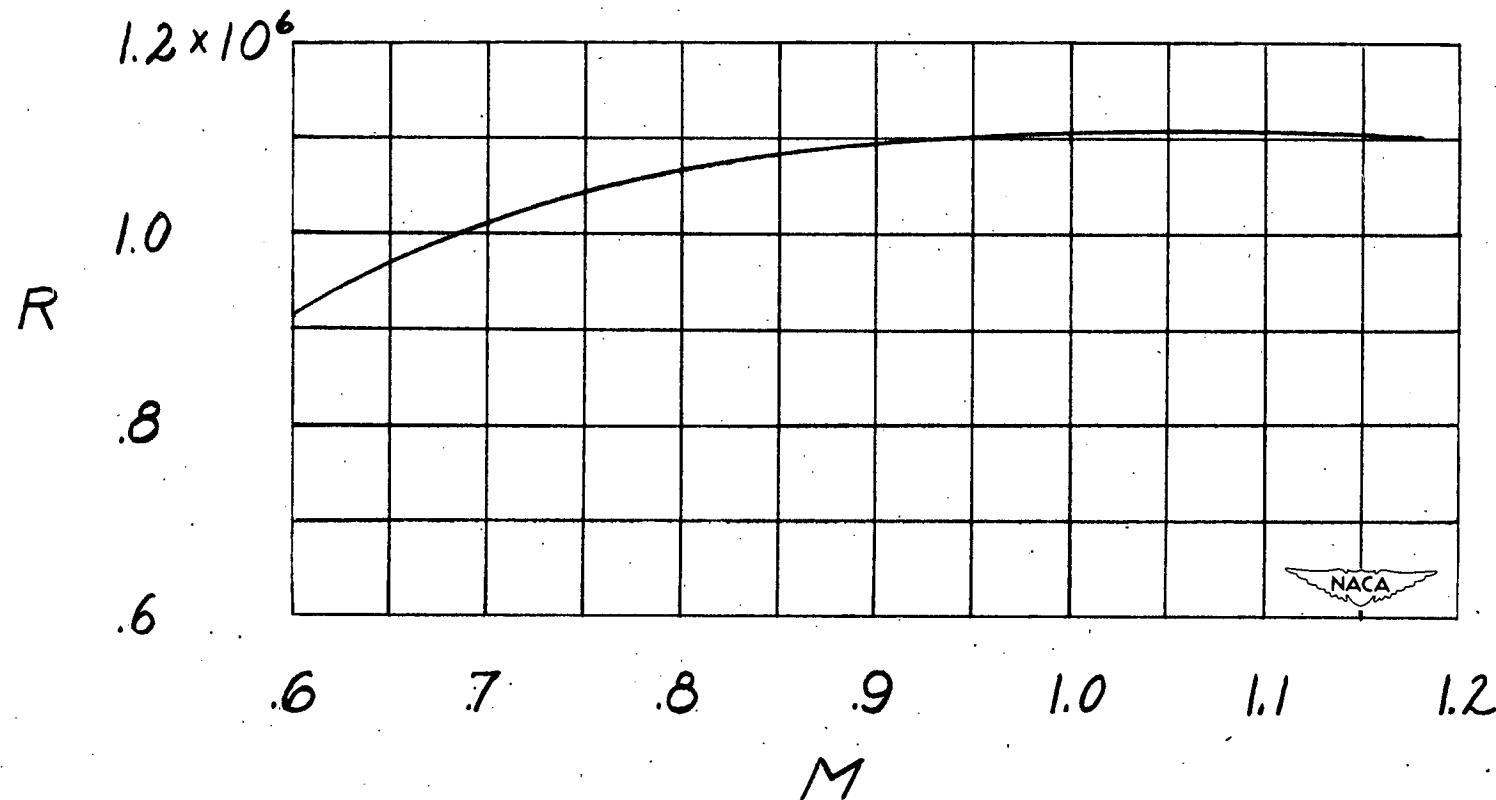


Figure 4.- Variation of average test Reynolds number with Mach number for the two wings having sweepback of  $20.55^\circ$ , an aspect ratio of 2.67, and a taper ratio of 0.5, one wing with and one wing without an end plate.

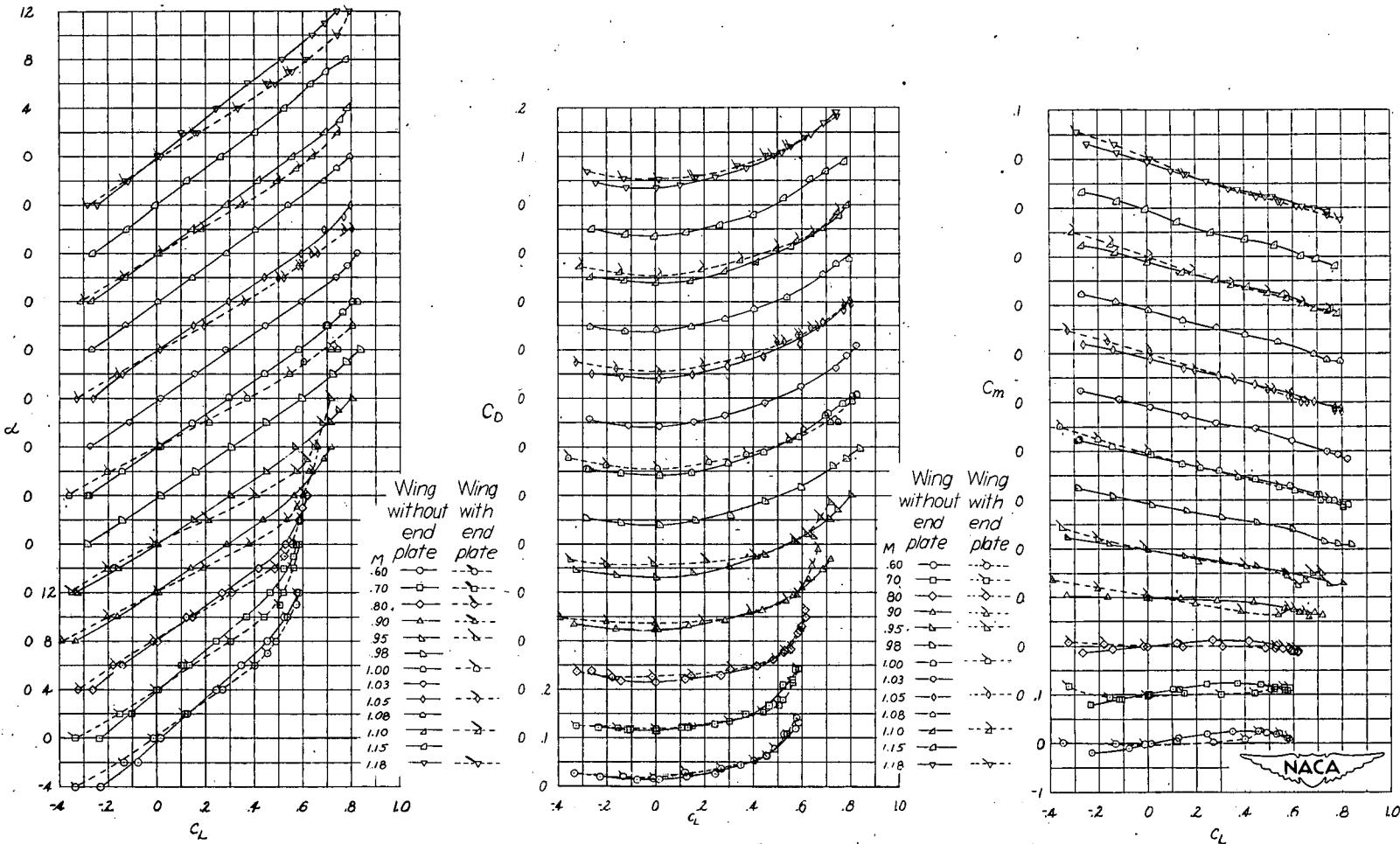


Figure 5.- Aerodynamic characteristics of the two wings having sweep-back of  $20.55^{\circ}$ , an aspect ratio of 2.67, and a taper ratio of 0.5, one wing with and one wing without an end plate.

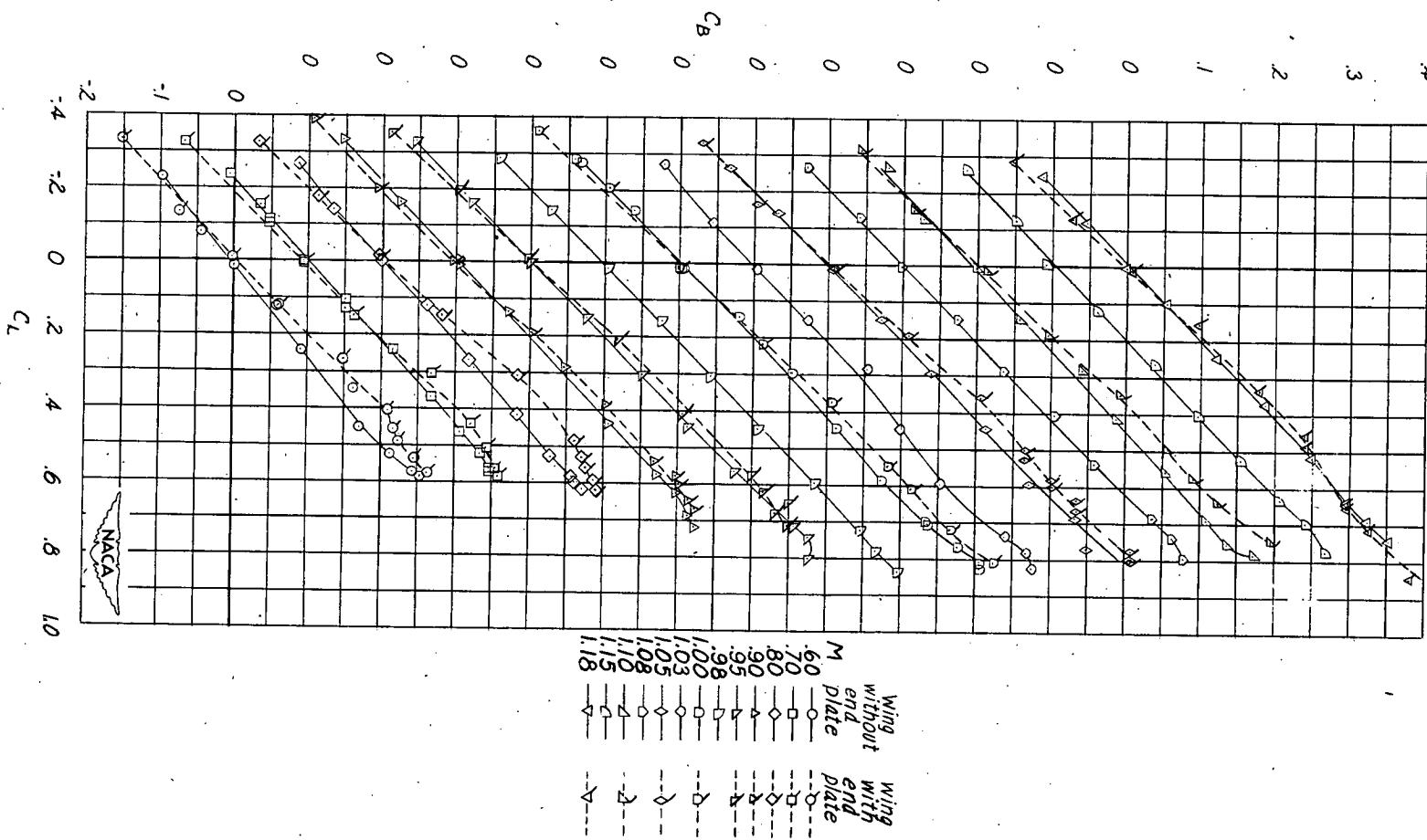


Figure 5.- Concluded.

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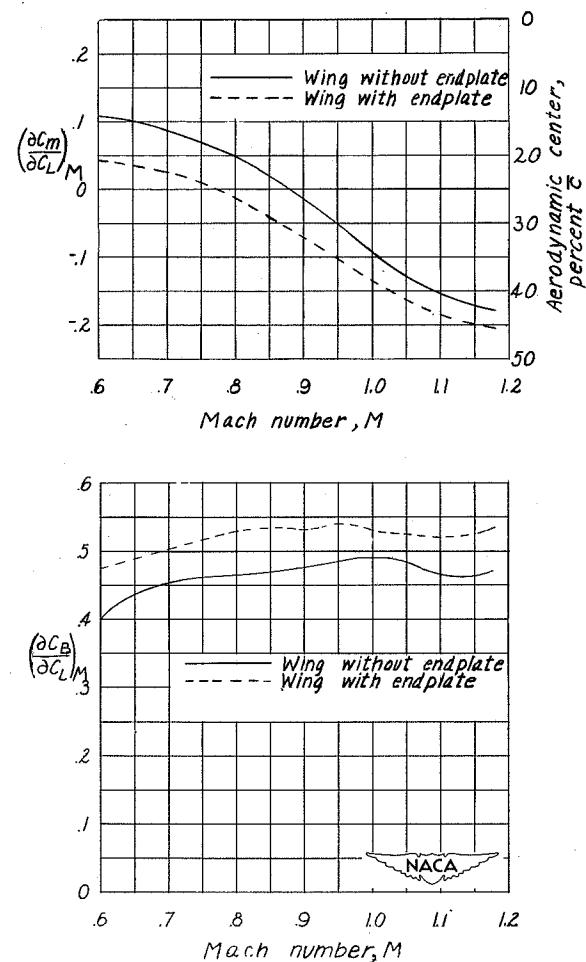
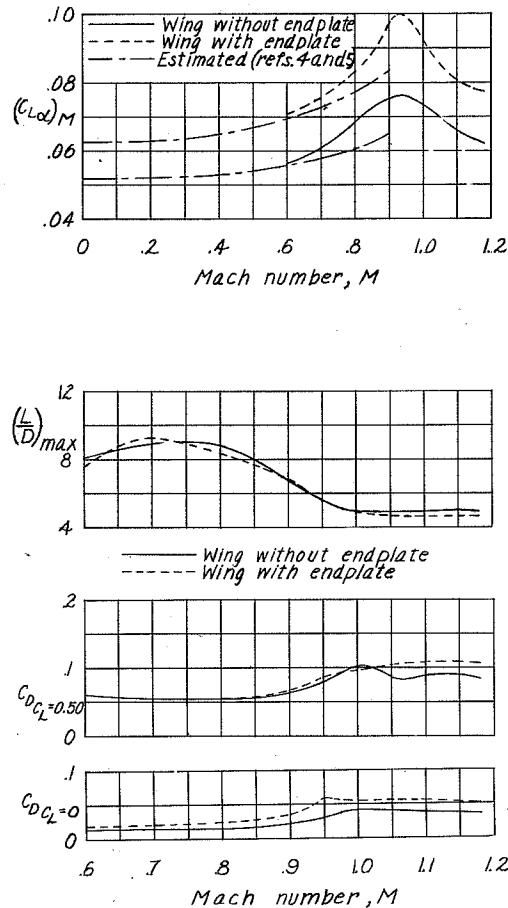


Figure 6.- Summary of the aerodynamic characteristics for the two wings having sweepback of  $20.55^\circ$ , an aspect ratio of 2.67, and a taper ratio of 0.5, one wing with and one wing without an end plate.